Cambridge Assessment International Education

Teaching Pack
Determining the principle of moments

Cambridge O Level
Physics 5054

Version 1.0

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Determining the principle of moments

This *Teaching Pack* focuses on determining the principle of moments using a metre rule and some masses.

This experiment has links to the following syllabus content (see syllabus for detail):

- 5.1 Moments

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 3.1 Balanced and unbalanced forces
- 4.1 Mass and weight

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about 22.1 Force on a current-carrying conductor, and 22.2 d.c. motor, as well as AS & A Level topics regarding rotational motion.

Briefing lesson: Determining the principle of moments

Resources	• a metre rule and some weights that can be suspended • a long candle, matches, two glasses, a long pin or needle, heat proof mat • Worksheets A and B
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe the moment of a force as a measure of its turning effect and give everyday examples • ***most*** learners should recognise that, when there is no resultant force and no resultant turning effect, a system is in equilibrium • ***some*** learners should be able to apply the principle of moments to different situations.

Timings	Activity
10 min	**Starter/Introduction** Display the question: *What would you do if you wanted to feel the moment?* Allow your learners to express what they might do 'to feel the moment'. Then pass around a meter rule with a weight that can be suspended at different places. Ask your learners to hold the metre rule horizontally and note the different moments when the weight's distance is varied. The difference between force and moment is felt.
10 min	**Main lesson** Ask learners if they can remember the effects of some resultant force (unbalanced forces) acting on an object. Encourage them to demonstrate their answers. Summarise the effects of a net force as presented in Worksheet A. Direct their attention to a door handle. Ask if they have ever seen a door handle which is near the hinges. Let them exchange ideas regarding the reason for the location of a door handle. Introduce the term 'moment' as the turning effect of a force and introduce the formula: moment = (force) × (perpendicular distance from the pivot)
15 min	Define the two possible directions of rotation: *clockwise* and *anti-clockwise*. Stress on the importance of identifying them. Give learners Worksheet B and ask them to answer Q1. Use the classroom door to demonstrate how you can counteract a turning effect of a force. First establish the fact that it is the sum of clockwise moments and the sum of anti-clockwise moments counteracting each other. Exemplify how to calculate the resultant (net) moment on an object. Learners answer Q2 on Worksheet B. Now link with rotational equilibrium: balanced moments. Stress that the condition of rotational equilibrium is named the 'Principle of Moments'. Introduce the condition of (static) equilibrium.
20 min	Make a candle seesaw by trimming the wick so both ends are exposed. Balance the candle by a needle through the centre. Rest the ends of the needle on a pair of drinking glasses on a heatproof mat. Ask learners: what do you think is going to happen when both ends of the candle is lit? Light the ends and allow the learners to observe. Initiate a discussion in class of explaining what they observed. As the wax drips, the centre of mass shifts, causing the candle to oscillate.
5 min	**Plenary** Ask learners to answer Q3 on Worksheet B.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Teacher Walkthrough video • Worksheets C, D and E

Learning objectives	By the end of the lesson: • ***all*** learners should be able to perform an experiment (involving vertical forces) to show that there is no net moment on a body in equilibrium • ***most*** learners should be able to perform and describe an experiment (involving vertical forces) to show that there is no net moment on a body in equilibrium • ***some*** learners should be able to demonstrate the principle of moments with more than two forces acting on a beam.

Timings	Activity
10 min	**Starter/Introduction** Give learners the following scenario: You need to turn a bolt using a wrench but the bolt will not turn. If you attached a rope to the wrench and pulled on the rope will the moment be increased if you pull hard on the rope? Allow learners some time to discuss. Then explain to learners that the moment would be the same if pulling on a rope or a wrench as pulling on the rope would not increase the size of the perpendicular distance from the pivot, which would remain the same.
5 min 15 min 15 min	**Main lesson** Demonstrate (briefly) how the experiment needs to be done. Then give learners Worksheet C. Learners should work in pairs or groups for this experiment. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate. When the experiment is complete, get learners to work on Worksheet D individually and then discuss their answers in their pairs/groups. If there is not sufficient time for learners to finish this, set it as a homework assignment.
15 min	**Plenary** Lead a Q&A session with Worksheet E. Check the answers.

Teacher notes

Watch the *Teacher Walkthrough* video for determining the principle of moments video and read these notes.

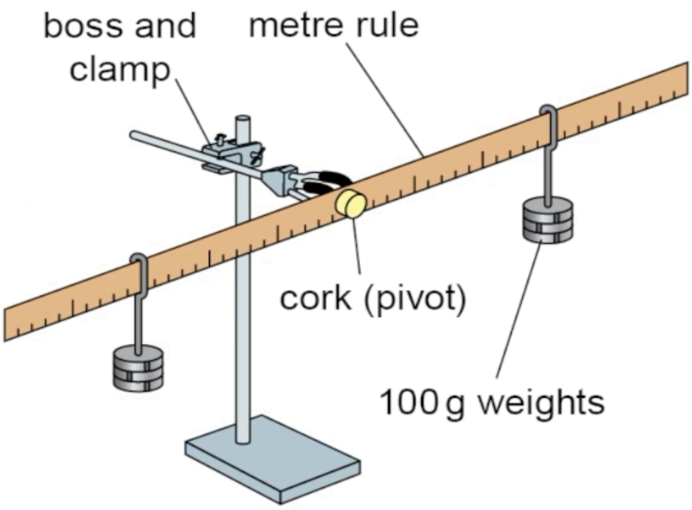
Each group will require:
- a boss and clamp stand set
- four mass hangers
- several 100 g masses
- two corks
- a long thin nail
- a metre rule with a hole at the centre.

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet C.

Before you begin
Plan how you will group your learners during the experiment session.
Think about:
- the number of groups you will need (group size 2–4 learners)
- if you want the apparatus set up fully partially or expect the pupils set it up.

Experiment
Walk around the learners during the experiment in case they encounter any difficulties.

Steps	Notes
1. Set up the apparatus as shown in the experiment diagram.	*You might like to set up the apparatus fully or partially in advance for learners depending on the ability and/or your expectations of the group. It is possible to use an optical pin instead of a nail.*
2. Hang the weights on the metre rule to achieve rotational equilibrium.	*If the ruler is not supported at the beginning, the mass hanger(s) will inevitably slide off.*
3. Add masses at different positions on the metre rule to maintain rotational equilibrium.	

Clean-up
After the experiment pupils should:
- tidy up their work space
- return all equipment to you or where they need to be collected.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual Experiment* video for determining the principle of moments • Worksheets F and G • Access to the internet

Learning objectives	By the end of the lesson: • ***all*** learners should be able to perform an experiment (involving vertical forces) to show that there is no net moment on a body in equilibrium • ***most*** learners should be able to perform and describe an experiment (involving vertical forces) to show that there is no net moment on a body in equilibrium • ***some*** learners should be able to demonstrate the principle of moments with more than two forces acting on a beam.

Timings	Activity
10 min	**Starter/Introduction** Give learners the following scenario: You need to turn a bolt using a wrench but the bolt will not turn. If you attached a rope to the wrench and pulled on the rope will the moment be increased if you pull hard on the rope? Allow learners some time to discuss. Then explain to learners that the moment would be the same if pulling on a rope or a wrench as pulling on the rope would not increase the size of the perpendicular distance from the pivot, which would remain the same.
25 min 15 min	**Main lesson** Give learners Worksheet F. They should answer the questions as the video plays. The video will stop and prompt them when they need to answer a particular question. Learners should now access the following simulation: https://phet.colorado.edu/sims/html/balancing-act/latest/balancing-act_en.html There are some guiding documents for teachers here: https://phet.colorado.edu/en/simulation/balancing-act If you don't have enough laptops/tablets for individual learners or groups of learners, show the simulation at the front of class and ask some learners to come and try it out. Alternatively, ask learners to try a balancing game with a ruler (as a beam) and a pencil (as a pivot). Different materials could be used to create different arrangements to demonstrate rotational equilibrium.
10 min	**Plenary** Give learners Worksheet G to complete. If there isn't enough time, this could be finished as a homework task.

Debriefing lesson: Using moments

Resources

- Several 10, 50 and 100 g masses, 30 cm rulers, small blocks to be used as pivots
- Access to an online quiz at 'Kahoot!'
- Worksheets H and I

Learning objectives

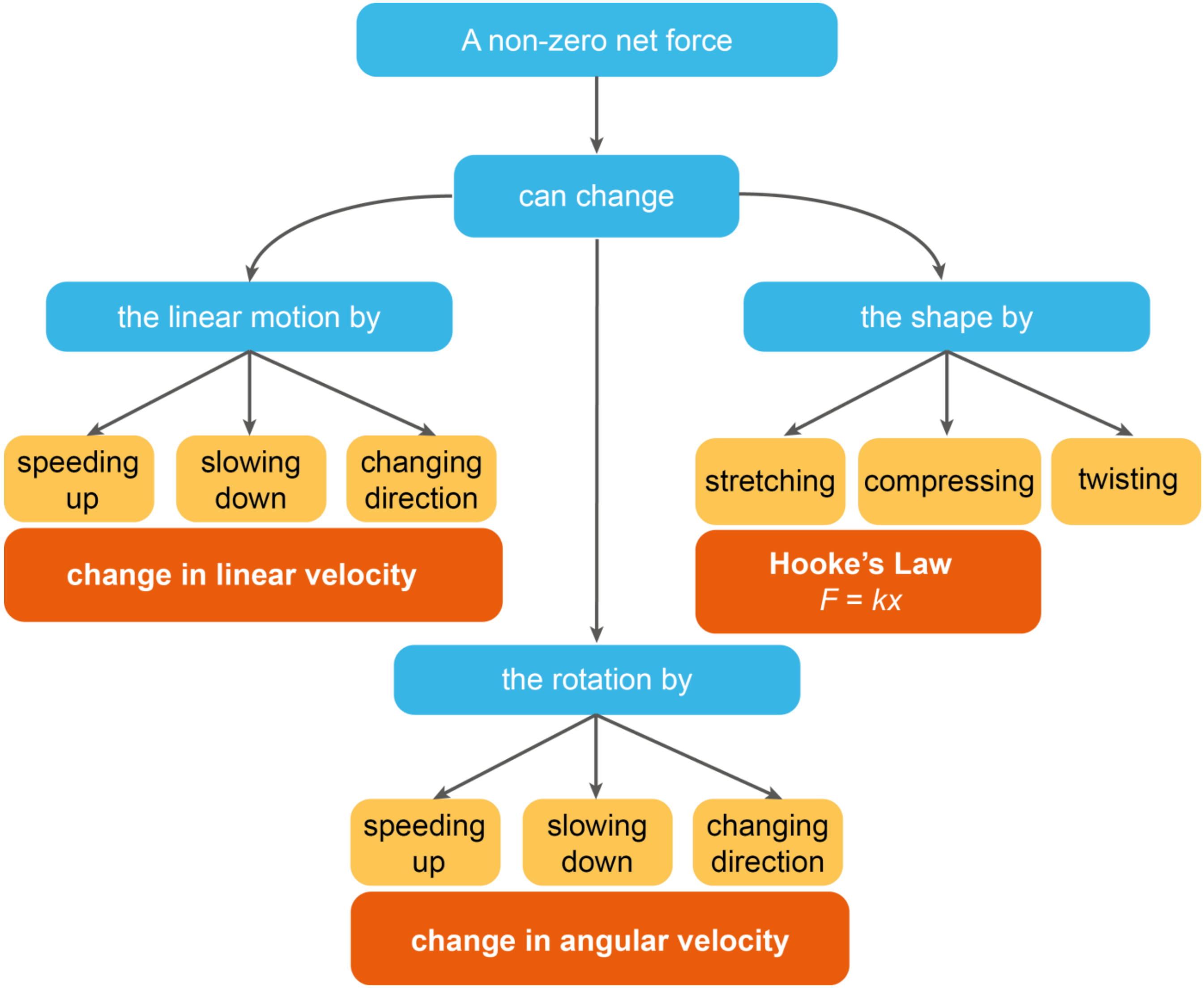
By the end of the lesson:

- ***all*** learners should describe the moment of a force as a measure of its turning effect and give everyday examples
- ***most*** learners should calculate moment using the product force × perpendicular distance from the pivot
- ***some*** learners should apply the principle of moments to the balancing of a beam about a pivot.

Timings	Activity
10 min	**Starter/Introduction** Give learners several masses, a small block to be used as a pivot and a 30 cm ruler (this can also be done in small groups). Ask them to create a balanced seesaw of their choice: one with the pivot in the middle, and one with the pivot somewhere else. Allow/encourage creativity and variety. Ask them to draw the condition and ask them to share their seesaw settings with others.
10 min	**Main lesson** Run the following Kahoot! at https://play.kahoot.it/#/k/197ca5ca-79c4-47ac-82d4-ef197091ff48 and hand out Worksheet H so that they can write the reasoning for their answers. If you cannot access Kahoot!, use Worksheet I by itself.
10 min	Next, ask learners to exchange the calculations for their seesaw settings when it is in rotational equilibrium. They should check each other's work. If they finish early, ask them to design a seesaw with some helium balloons attached OR you may direct them to http://www.freezeray.com/flashFiles/balancedBeam.htm for a simple demo of a balanced beam.
20 min	Hand out Worksheet I. Learners should work either individually or in pairs. When finished, they should swap their answers with another group and peer assess using the answers provided.
10 min	**Plenary** Ask learners the question: Why does a ball roll down a hill? Allow them to discuss their answer in groups. Stating that 'because of gravity / weight' is an incomplete answer. Gravity would have it slide down the hill. The fact that it rolls, or rotates, is evidence of unbalanced moments.

Worksheets and answers

Worksheet A: The effect of a net force

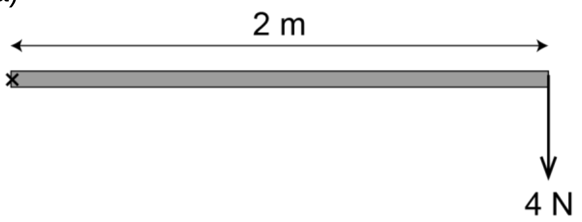


Worksheet B: Moments

Please answer the following questions by showing your work in full detail.

1. What is the turning effect of each force shown in the diagrams?

(a)



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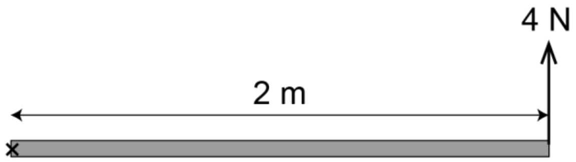

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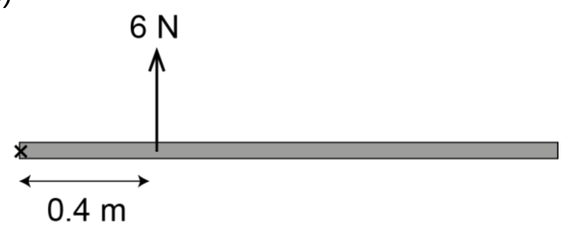
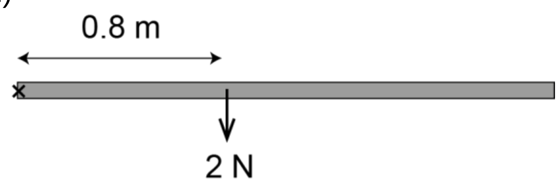
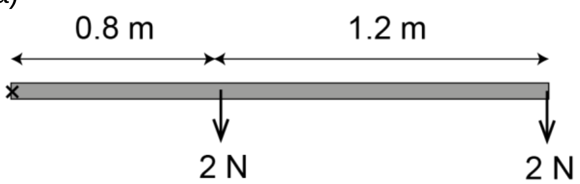


(d)



2. Calculate the resultant (net) moment for each case below.

(a)



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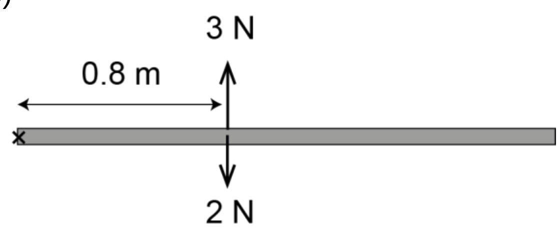

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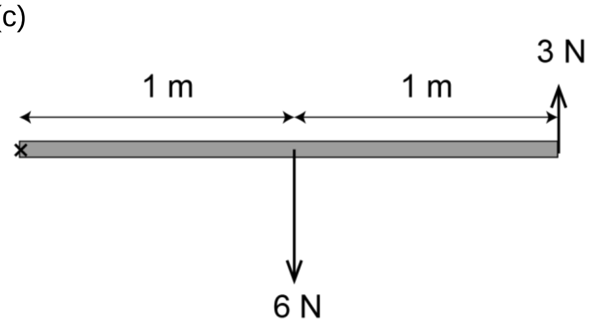

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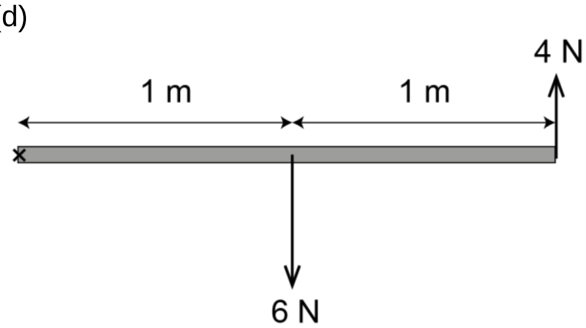
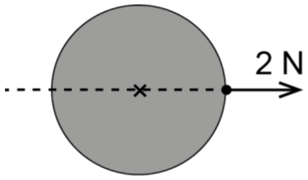


Worksheet B: Moments, continued

3. Below top-view figures show all horizontal forces acting on some homogeneous circular disks on a flat surface. ‘x’ shows the centre of the disk. You can ignore the vertical forces. State and explain if the objects are in equilibrium.

(a)



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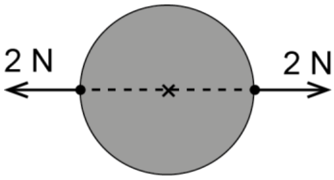

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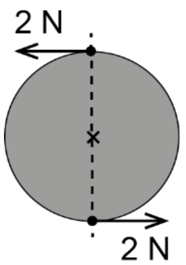

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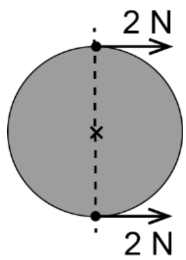
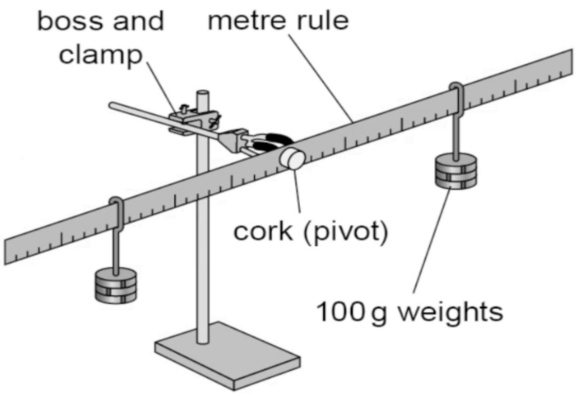


Worksheet C: Method

(1) Set up the apparatus as shown below:



(2) Add the mass hanger with a total mass of 100 g to the left-hand side of the metre rule 10 cm away from the pivot. Keep the ruler horizontal by supporting it with your hand.
(3) Add another mass hanger with a total mass of 100 g to the right-hand side.
(4) The right-hand side weight is moved gently either away from or towards the pivot point until the metre rule is balanced again.

Keep supporting the ruler as you try to achieve the rotational equilibrium, with ruler staying horizontal.

(5) Record the push of each mass hanger and their perpendicular distance to the pivot in a data table.

An example data table is provided on the reverse of the worksheet.

Remember the applied force on the ruler is the push by the mass hanger with slotted masses on it. This push is equal in size to the weight of the hanger and the slotted masses together. We will take gravitational field strength as $10\frac{N}{kg}$.

(6) While keeping the ruler horizontal by supporting it by hand, add a 100 g slotted mass on the left-hand hanger. Slide the right-hand hanger gently until the metre rule is balanced again. Record the new values in your data table.
(7) Try different arrangements of your own on two opposite sides of the pivot so that the ruler is in rotational equilibrium. Fill in your data table up to at least seven different combinations.
(8) Calculate the clockwise and anti-clockwise moments and fill in the data table.

Worksheet C: Method, continued

Left side of the pivot			Anti-clockwise moment / N mm	Right side of the pivot			Clockwise moment / N mm
Number of 100 g masses	Applied force on the ruler / N	Distance to the pivot / mm		Number of 100 g masses	Applied force on the ruler / N	Distance to the pivot / mm	

Worksheet D: Experiment questions

1. Why is it suggested that you keep the ruler horizontal by supporting it with your hand?

   ....

2. Describe how you used the retort stand for this practical.

   ....

   ....

3. Why is a metre rule a better choice when compared to a 30 cm ruler?

   ....

4. The sample data given in the first row of table, below the column headings has a cell for “Distance to the pivot / mm”, reading 196. Why is not written as 196.0?

   ....

   ....

5. How else do you think you can present the collected data?

   ....

   ....

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   ....

   ....

6. What conclusion can you draw from the data collected?

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Worksheet D: Experiment questions, continued

7. What could be possible causes of uncertainty, in your data or conclusion?

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8. What was your conclusion? Justify and explain.

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9. Comment critically on the procedure or the point of practical detail and suggest at least two appropriate improvements?

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10. Evaluate the quality of data?

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Worksheet E: Summary questions

1. What is moment?

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2. How do we measure it?

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 ....

 ....

3. What is principle of moments?

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 ....

 ....

4. How do we check the principle?

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Worksheet F: Virtual practical questions

Answer the following questions whilst watching the Virtual Experiment video.

1. What other effects could a resultant force create on object?

   ....

   ....

   ....

2. Which statement below is correct for an object in rotational equilibrium?

   A It keeps rotating at a constant speed in the same direction, or is not rotating at all.
   B Its rotation speed decreases in time.
   C Its rotation speed increases in time.

3. If the sum of all clockwise moments is equal to the sum of all anticlockwise moments around a point, the object is

   A equilibrium.
   B in rotational equilibrium.
   C stationary.
   D balanced.

   Although the video says, '*hang a weight hanger with the 100 g weight on the left-hand side of the centre of the ruler, 10 cm away from the pivot*', it shows a 50 g mass already added to the hanger. How can you explain that?

   ....

   ....

   ....

Worksheet F: Virtual practical questions, continued

4. The applied force on the ruler is assumed to be equal to the number of 100 g masses used. What is the reason for that assumption?

   ....

   ....

   ....

5. Why do we need to change the location of 100 g mass on the right-hand side?

   ....

   ....

   ....

6. What other way can you suggest to check the relationship between anti-clockwise and clockwise moments?

   ....

   ....

   ....

Worksheet G: Applying your knowledge

Answer each of these questions.

1. Why can you lift so much more with a wheelbarrow than you can carry?

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....

....

....

....

2. If you use a hammer to pull out a nail, you are more likely to succeed than using your bare fingers. How can you explain this?

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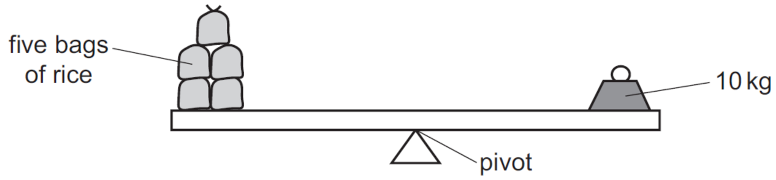
Worksheet G: Applying your knowledge, continued

3. Five identical bags of rice are balanced on a uniform beam by an object of mass 10 kg.



Two more identical bags of rice are added to the other five. The average position of the bags on the beam does not change.

What mass now balances the bags?

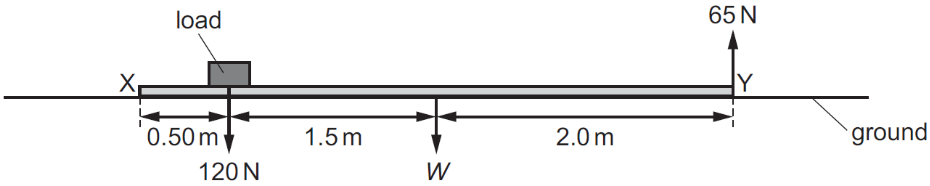
....

....

....

....

4. A long plank XY lies on the ground. A load of 120 N is placed on it at a distance of 0.50 m from the end X, as shown.
End Y is lifted off the ground. The upward force needed to do this is 65 N.



In the diagram, *W* is the weight of the plank, acting at its mid-point.
What is the value of *W*?

....

....

....

....

Worksheet H: Moments – quick quiz

Answer each question below and give an explanation for your response.

1. Any force acting on an object creates some turning effect, named as moment.

   TRUE **FALSE**

   Explanation:

2. The turning effect of a force will increase if the force itself increases.

   TRUE **FALSE**

   Explanation:

3. The turning effect of a force will increase if the perpendicular distance from the pivot decreases.

   TRUE **FALSE**

   Explanation:

4. Which sentence expresses the principle of moments the best?

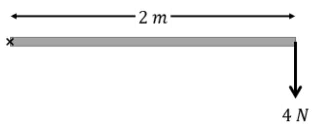
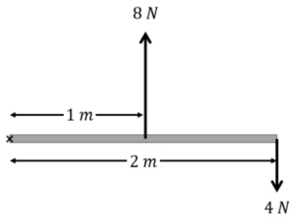
   A Force multiplied by the distance from the pivot is equal to moment.
   B If the clockwise moments are equal to the anti-clockwise moments, the object is in rotational equilibrium.
   C If the sum of the clockwise moments is equal to the sum of the anti-clockwise moments, the object does not rotate.
   D If the sum of the clockwise moments is equal to the sum of the anti-clockwise moments, the object is in rotational equilibrium.

   Explanation:

Worksheet I: Calculations practice

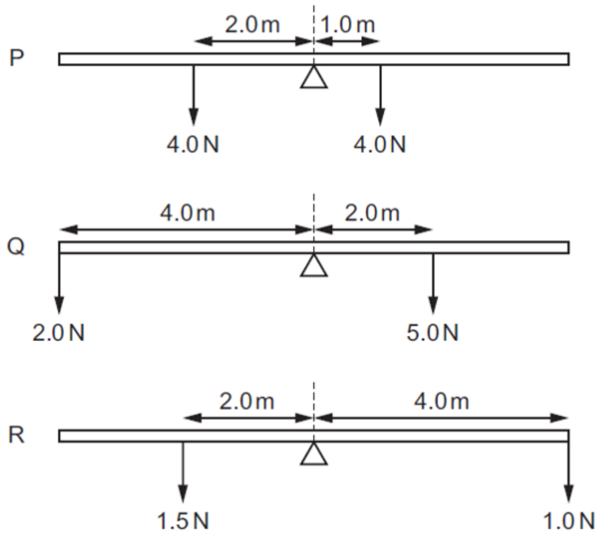
Answer each question and give an explanation for your response.

1. Check if the following beams are in rotational equilibrium. The diagrams show all the forces acting on the beams. ‘x’ is where the pivot is located.

		
Explanation:	Explanation:	Explanation:

2. The diagrams show three uniform beams P, Q and R, each pivoted at its centre.

   The two forces acting on each beam are also shown.



Which beams rotate clockwise?

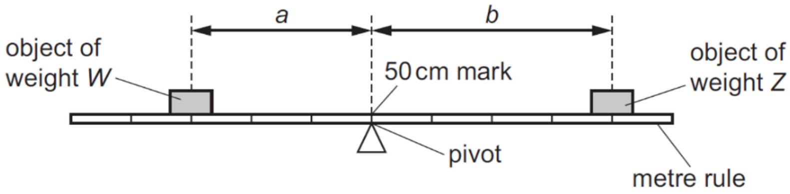
....

....

....

Worksheet I: Calculations practice, continued

3. The diagram shows an object of weight *W* and an object of weight *Z* balanced on a uniform metre rule.



What is the mathematical link between *W*, *Z*, *a* and *b*?

....

....

....

4. What is the function of the two corks?

....

....

....

5. The clockwise moment was not always exactly equal to the anti-clockwise moment when the ruler was balanced. What might be the reason(s) for it?

....

....

....

....

Worksheet B: Suggested answers

1.

moment = force x perpendicular distance from the pivot

(a)

4 N x 2 m = 8 N m (clockwise)

(b)

4 N x 2 m = 8 N m (anti-clockwise)

(c)

6 N x 0.40 m = 2.4 N m (anti-clockwise)

(d)

2 N x 0.80 m = 1.6 N m (clockwise)

2.

(a)

2 N x 0.8 m = 1.6 N m (clockwise)

2 N x 2 m = 4 N m (clockwise)

Net moment: 1.6 N m + 4 N m = 5.6 N m (clockwise)

(b)

2 N x 0.8 m = 1.6 N m (clockwise)

3 N x 0.8 m = 2.4 N m (anti-clockwise)

Net moment: 2.4 N m – 1.6 N m = 0.8 N m (anti-clockwise)

(c)

3 N x 2 m = 6 N m (anti-clockwise)

6 N x 1 m = 6 N m (clockwise)

Net moment: 6 N m – 6 N m = 0 N m

(d)

4 N x 2 m = 8 N m (anti-clockwise)

6 N x 1 m = 6 N m (anti-clockwise)

Net moment: 8 N m – 6 N m = 2 N m (anti-clockwise)

3.

(a)

Net force is non-zero.
Net moment is zero.
System is not in equilibrium.

(b)

Net force is zero
Net moment is zero.
System is in equilibrium.

(c)

Net force is zero.
Net moment is non-zero.
System is not in equilibrium.

(d)

Net force is non-zero.
Net moment is zero.
System is not in equilibrium.

Worksheet D: Suggested answers

1. *To prevent the mass hangers from falling off the ruler.*

2. *The retort stand is used to create a supporting pivot for the ruler (pin/nail-cork-boss-clamp).*

3. *A 30 cm ruler is too short to allow for a big enough range of masses to hang on.*

4. *The column heading indicates that the unit should be in millimetres.*
   The minimum distance the ruler can measure is 1 mm not 0.1 mm as 196.0 mm would suggest.

5. *Plot a graph of clockwise moment versus anti-clockwise moment.*
   A best-fit line or curve could be drawn to quantify the relationship between them.

6. *When the ruler is in rotational equilibrium, the sum of clockwise moments is equal to the sum of anti-clockwise moments.*

7. Any of the following:

   - *Difficulty in achieving balance* **OR** *difficulty in positioning load exactly, e.g. load covers rule markings* **OR** *uncertainty about position of where the load pushes the ruler down.*
   - *Ruler won't balance exactly allowing to tip one way then the other.*
   - *Have repeat measurements: take the mass hangers off the ruler and position again for equilibrium, then find the average distance.*
   - *Difficulty obtaining balance as ruler tips one way then the other.*
   - *Mass/hanger obscuring marks on ruler.*

8. *The ruler is in rotational equilibrium when the sum of clockwise moments is (almost) equal to the sum of anti-clockwise moments. I know that the net moment should be zero for rotational equilibrium.*

Worksheet D: Suggested answers, continued

9.

- *There were no repeat measurements.*
- *Each measurement should be repeated at least two more times and averages should be used to increase the reliability of the data.*
- *The corks might have created some friction force (contributing to clockwise or anti-clockwise moments).*
- *Some lubricant material might be used to minimise the friction.*
- *Mass hangers' hook was blocking a large area on the ruler, making it difficult to identify the exact point the push of the weight acts on.*
- *Smaller mass hangers could be used such that their hooks would be thinner, obstructing a smaller region on the ruler when hung.*
  The ruler was not horizontal enough due to fact that the hole was not at the correct point.
- *Ruler could be prepared better in advance.*

10.

- *Having no repeats lowers the quality of the data by decreasing the reliability.*
- *Using the number of slotted masses as the pushing force on the ruler in newtons lowers the quality as slotted masses may not be exactly 100 g each.*
- *In theory, the sum of clockwise moments should be equal to the sum of anti-clockwise moments for rotational equilibrium. Although the values were very close to each other, they were not identical.*

Worksheet E: Suggested answers

1. *The turning effect of a force is called moment of the force.*

2. *We need to measure the size of the force and the perpendicular distance from the pivot to the force. The direction of rotation needs to be identified.*

3. *If the ruler is in rotational equilibrium, the sum of clockwise moments should be equal to the sum of anti-clockwise moments.*

4. *We used a ruler, which was free to rotate around a pivot in the mid-point. We hung masses to apply downward pushes on the ruler, creating some clockwise and anti-clockwise moments.*

   Moments are calculated by using the formula:

   $$\text{moment} = \text{force} \times \text{perpendicular distance from the pivot}$$

Worksheet F: Suggested answers

1. Acceleration (speeding up, slowing down, and changing direction/change in velocity).

   Change in shape.

2. A

3. B

4. The weight hanger itself has a mass of 50 g.

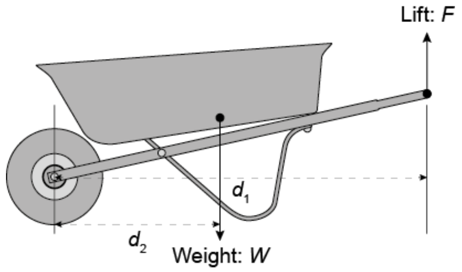
5. Every 100 g mass on the Earth has about 1 N of weight (the push on the ruler is equal to the size of weight of the hung mass).

6. Adding another 100 g mass on the left-hand side increases the anti-clockwise moment. To achieve the rotational equilibrium, the clockwise moment should also increase. This could be done by increasing the perpendicular distance from the force to the pivot.

7. A graph of clockwise moments versus anti-clockwise moments could be plotted (the plotted graph should have a gradient of almost one, with almost zero y-intercept).

Worksheet G: Suggested answers

1.



The upward force you apply to the handles, F, creates an anti-clockwise turning effect on the wheelbarrow around the axis of the wheel: $F \times d_1$. The total weight of the load and the wheelbarrow itself, W creates a clockwise moment around the same axis: $W \times d_2$. Since $d_1 > d_2$, the lifting force could be smaller than the weight.

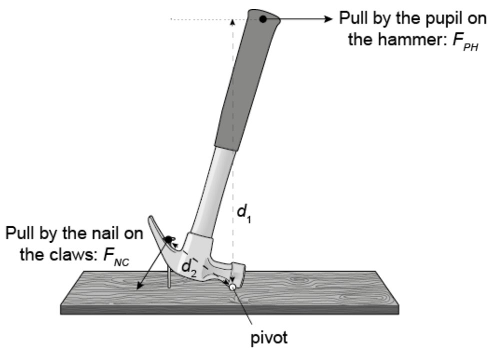
For example:

$$F = 100 \text{ N}, d_1 = 0.80 \text{ cm} = \text{anti-clockwise moment: } 80 \text{ N cm}$$

$$W = 400 \text{ N}, d_2 = 0.20 \text{ cm} = \text{clockwise moment: } 80 \text{ N cm}$$

One can lift a total of 40 kg with a force of 100 N. For a large distance, you do not need to apply as much force to generate a moment.

2.



$F_{PH} \times d_1 = F_{NC} \times d_2$

Since $d_1 > d_2$, $F_{PH} < F_{NC}$

The hammer claw pulls the nail out. The nail is equally pulling the claw downwards, creating a moment around the point where the hammer contacts the surface. You exert a force on the other end of the hammer, creating a moment. These moments are equal, but the difference in distance means that the forces applied are not equal in size: you can apply a small force to create the same turning effect as the one created by the force between the claw and the nail.

Worksheet G: Suggested answers, continued

3.

Solution based on algebra:

One bag of rice = x, the distance between the five bags of rice and the pivot = d_1 and the distance between the five bags of rice and the pivot = d_2. These distances do not change as the question states.

Initially: $5x \times d_1 = 10\ \text{kg} \times 10\frac{N}{kg} \times d_2$ *[Equation 1]*

New arrangement: $7x \times d_1 = (\text{new mass}) \times 10\frac{N}{kg} \times d_2$ *[Equation 2]*

Dividing Equation 2 by Equation 1:

$$\frac{7x \times d_1 = (\text{new mass}) \times 10\frac{N}{kg} \times d_2}{5x \times d_1 = 10\ \text{kg} \times 10\frac{N}{kg} \times d_2} = \frac{7}{5} = \frac{(\text{new mass})}{10\ \text{kg}}$$

$$(\text{new mass}) = \frac{70\ \text{kg}}{5} = 14\ \text{kg}$$

OR

Simpler solution:

Every five bags of rice balances out 10 kg mass, therefore one bag needs 2 kg of mass. An additional two bags would need an additional 4 kg mass, making the total new mass 14 kg.

4.

When the plank is lifted, it will rotate around point X.

Sum of clockwise moments: $[W \times (0.50\ \text{m} + 1.5\ \text{m})] + [120\ \text{N} \times 0.50\ \text{m}]$

Sum of anti-clockwise moments: $65\ \text{N} \times (0.50\ \text{m} + 1.5\ \text{m} + 2.0\ \text{m})$

The moment by 65 N lifting force should be at least as large as the moment created by the weight and the load together:

$$[W \times (0.50\ \text{m} + 1.5\ \text{m})] + [120\ \text{N} \times 0.50\ \text{m}] = 65\ \text{N} \times (0.50\ \text{m} + 1.5\ \text{m} + 2.0\ \text{m})$$

$$W \times 2.0\ \text{m} + 60\ \text{N m} = 260\ \text{N m}$$

$$W = 100\ \text{N}$$

Worksheet H: Suggested answers

1. *FALSE*

Explanation:

A force acting on an object would create some turning effect only if there is a distance between (the line of action of) the force and the pivot.

2. *TRUE*

Explanation:

moment = force × distance from the pivot
The larger the force is, the bigger the moment is, assuming the distance stays the same.

3. *FALSE*

Explanation:

moment = force × distance from the pivot
The smaller the distance is, the smaller the moment is, assuming the force stays the same.

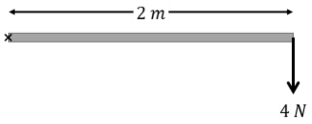
4. ***D***

Explanation:

A *is not a correct statement for the principle of moments. It simply describes how moment is calculated.*
B *is not a complete description: we need to compare the sum of clockwise moments to the sum of anticlockwise moments.*
C *is not correct: if the sums are equal to each other, the object may keep rotating at the same speed, in the same direction, if it was already rotating.*

Worksheet I: Suggested answers

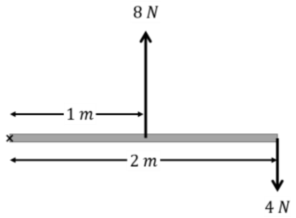
1.



Clockwise moments:
4 N x 2 m = 8 N m

Anti-clockwise moments:
None

Not in rotational equilibrium.



Clockwise moments:
4 N x 2 m = 8 N m

Anti-clockwise moments:
8 N x 1 m = 8 N m

In rotational equilibrium.

Clockwise moments:
None

Anti-clockwise moments:
None

In rotational equilibrium.

2.

P: 4.0 N × 2.0 m = 8.0 N m anti-clockwise; 4.0 N × 1.0 m = 4.0 N m clockwise
Since the sum of anticlockwise moments is bigger than the sum of clockwise moments, it will rotate anticlockwise

Q: 2.0 N × 4.0 m = 8.0 N m anti-clockwise; 5.0 N × 2.0 m = 10.0 N m clockwise
Since the sum anticlockwise moments is smaller than the sum of clockwise moments, it will rotate clockwise.

R: 2.0 N × 1.5 m = 3.0 N m anti-clockwise; 1.0 N × 4.0 m = 4.0 N m clockwise
Since the sum anticlockwise moments is smaller than the sum of clockwise moments, it will rotate clockwise.

3.

A uniform metre rule's weight will be acting at its middle, where the pivot is. Therefore the support by the pivot on the rule will not have any turning effect. If it is balanced, the sum of clockwise moments, $Z \times b$, must be equal to the sum of anticlockwise moments, $W \times a$:

$$W \times a = Z \times b$$

Worksheet I: Suggested answers, continued

4.

The corks keep the ruler on the nail throughout the investigation. The nail and the hole on the ruler function as a free to rotate axis. The corks act like washers.

5.

The positions of the mass hangers may not have been read accurately.

The friction force between the nail and the ruler may have changed from one arrangement to other, creating some unaccounted moment.

The added masses may not be exactly 100 g and or identical to each other.

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